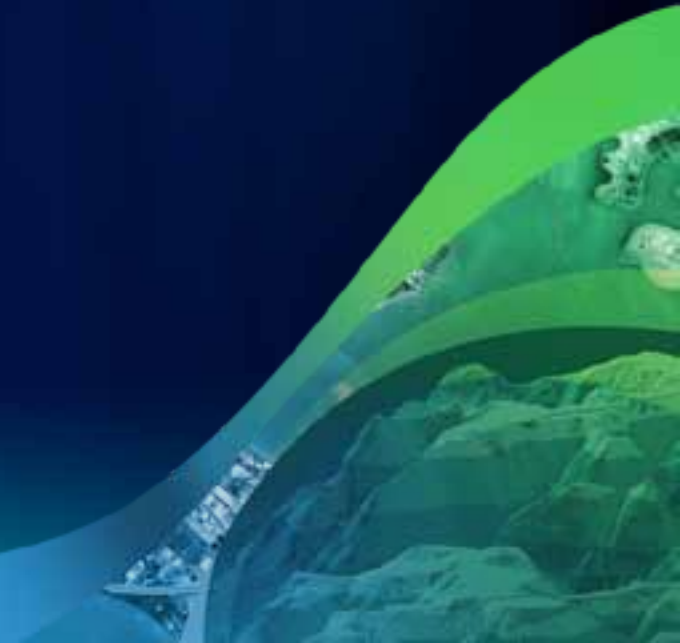




**Esri International User Conference | San Diego, CA**  
**Technical Workshops | July 11 – 15, 2011**

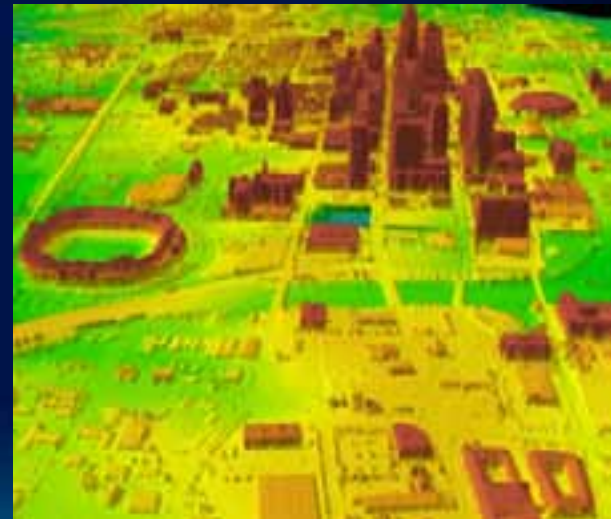
# **3D Analyst – Working with Terrain Datasets**

Lindsay Weitz



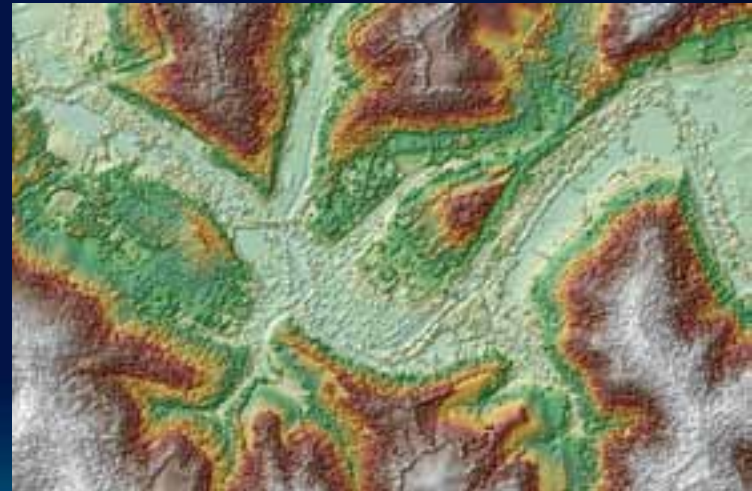
# Content

- Overview
- Terrain dataset implementation
- Terrain dataset analysis
- Demonstration
- Suggestions
- Resources



# Terrain Dataset

- A Terrain is a multi-resolution surface created from measurements stored in feature classes
- Typical applications:
  - Topographic mapping
  - Bathymetric mapping
- Typical data sources:
  - Photogrammetric data
  - Lidar
  - Sonar



# Motivating Forces

- **Scalability**
  - Large collections of mass point data (e.g. LIDAR) have been a problem
- **Data integration**
  - Need surface to live with source data
- **Data management**
  - Database tools
  - Editing/update
  - Multi-user

## Limitations to Overcome

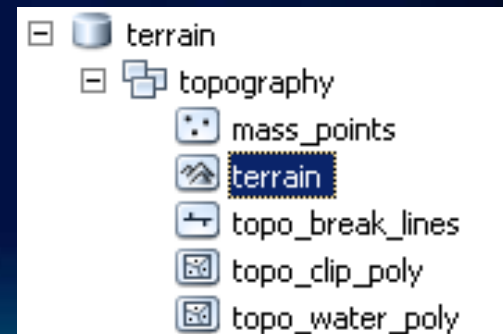
- **TINs have an effective limit of 20 million points**
  - Based on 2GB per process limit of Win32
  - It's recommended not to go over 3-5 million
- **Updating TINs relative to edits of source measurement data is difficult**
  - They are disconnected
  - Easiest thing to do is rebuild from scratch
- **TINs only support Workstation Arc/Info projections**
- **Rasters are derivative**
  - Difficult to update without rebuilding from source data

# **Need for Maintaining Topographic Baseline**

- **Many organizations are charged with keeping accurate and up to date topographic/bathymetric surfaces**
  - **Construction projects/permitting**
  - **Hydrologic/hydraulic modeling**
  - **Navigation**
- **Terrains offer database oriented solution for managing source data from which these surfaces are derived**

# What are Terrain Datasets?

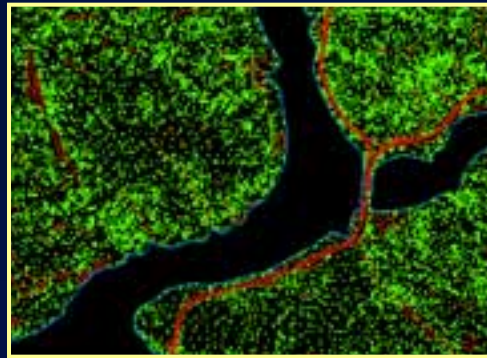
- Terrain datasets live inside feature datasets within the geodatabase
- Identify which feature classes participate and how they contribute
- Rules specify how features are used to define a surface





# Multi-Resolution Surface Model

Points and Breaklines



Terrain Pyramids



Thinned Point Set



Full Resolution

Multi-resolution terrain dataset (TIN structure)



# Implementation – Levels of Detail

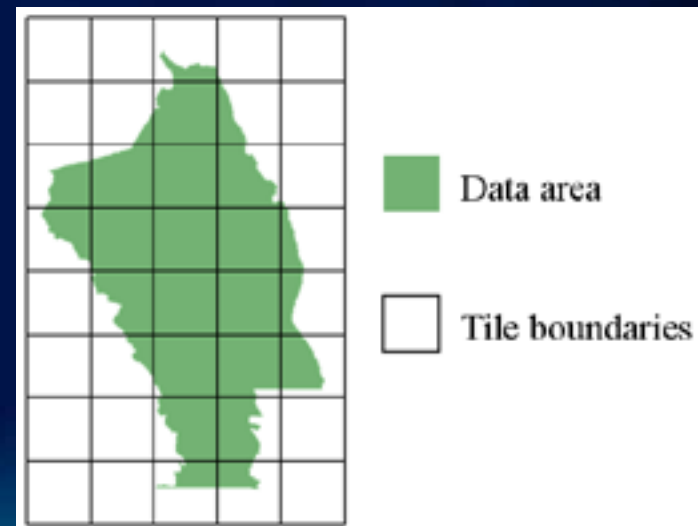
- **TIN surface generated on-the-fly for given area of interest and level of detail**
- **Supports point, multipoint, polyline, and polygon based features**
- **Seamless**
- **Fast**
- **Scalable**

## Implementation - Tiling

- Spatial coherence and *tiling* (point clustering)
- Z tolerance and *vertical indexing*
- Measurement update and *dirty-areas*
- Localized processing

# Implementation - Tiling

- Data is structured, internally, into tiles
- Spatially coherent parts
- Each tile contains a manageable amount of data
- Facilitates processing large amounts of data



# Tile System Definition

- **Defined by nominal point spacing and coordinate system**
  - Point spacing controls tile size
  - Coordinate system defines origin and extent
- **Terrain maintains properties that define tile system**
  - Tile boundaries are not stored
  - Mathematically derived on-demand

# Preventing/Reducing Tile Artifacts

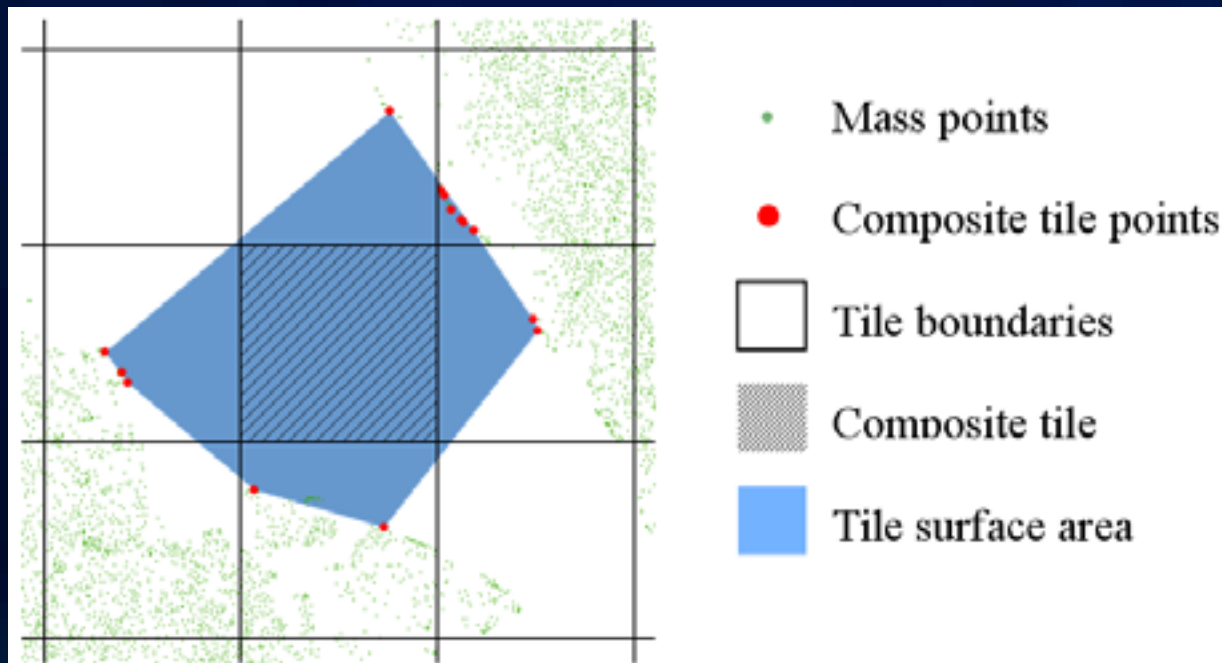
- **Problem associated with generic tile based processing**
  - **Interpolation neighborhoods are incomplete around tile boundaries**
  - **Artifacts when merging results of interpolation for multiple tiles**
- **Terrains address this issue automatically**
  - **Overlapped tiles provide a solution**
  - **Since neighborhoods are well defined around neat line boundaries tile derivatives merge seamlessly**

# Preventing/Reducing Tile Artifacts

- **Systems that only use overlapped tiles can still have problem with incomplete or empty tiles**
  - **Occur over water bodies, obscured areas**
- **Terrain handles these problematic tiles automatically by identifying and flagging them as *composite* tiles**
  - **Include references to nearest points in surrounding tiles**
  - **Complete surface definition for area represented by tile**

# Composite Tiles

Tile in center is void of samples but references those in neighboring tiles. Triangulation of those points covers the tile.






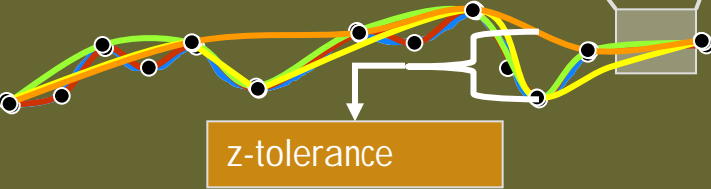




# Vector Based Pyramids

- Similar to raster pyramids in concept, but comprised of source measurements
- Point thinning
  - Heavy thinning for coarse levels
  - Lighter thinning for more detailed levels
  - No thinning at full resolution
- User defined scale threshold associated with each level
- For analysis as well as display
- Two pyramiding techniques: Z Tolerance or Window Size

## **Z Tolerance Pyramid**

- **TIN based decimation**
- **Generalized surface, for each pyramid level, within user defined vertical accuracy of full resolution surface**
- **Appropriate for bare earth data**
- **Should not be used with 1<sup>st</sup> return lidar surfaces (i.e., buildings and vegetation)**

# Z Tolerance Pyramid

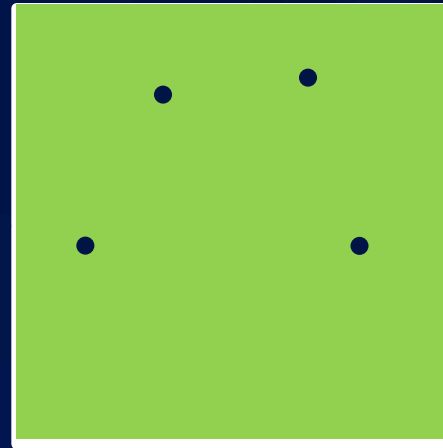
Points	Levels of Detail	Z-Tolerance	Scale	
	0	0	1:1	 <p>The distance between the lower resolution surfaces and the full resolution surface will not exceed a given Z-tolerance.</p>
	1	1	2500	
	2	5	10,000	
	3	10	50,000	
	4	20	100,000	

# Window Size Pyramid

- Simple binning or block filter
- Space partitioned into squares and one or two points selected for each square
- Selection criteria:
  - Min z, max z, min and max z, closest to mean z
- Effective for all data types
- Should be used with 1<sup>st</sup> return lidar

# Window Size Pyramid

Level	Window Size	Scale
0	0	1:1
1	2	2500
2	4	5,000
3	8	10,000

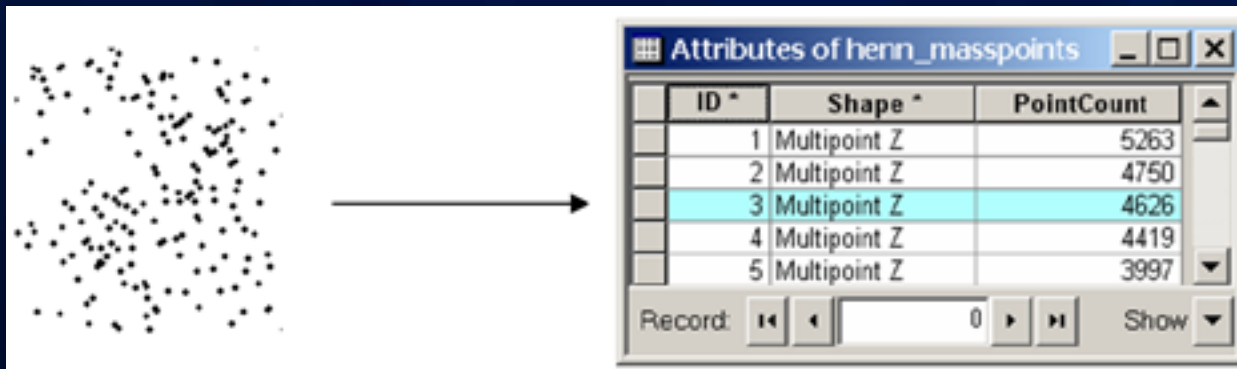


# Point Clustering

- One database row per point is too expensive
- Instead, points belonging to same tile and pyramid level are grouped into *multipoints*
- A multipoint is stored as an individual shape occupying one database row
- Reads and writes become more efficient
- Storage cost is reduced
- Only measurements are stored, TINs built on-the-fly

# Point Clustering

- Many points are combined into a shape called a multipoint that is stored using one database row.





# Input Data Formats - LAS

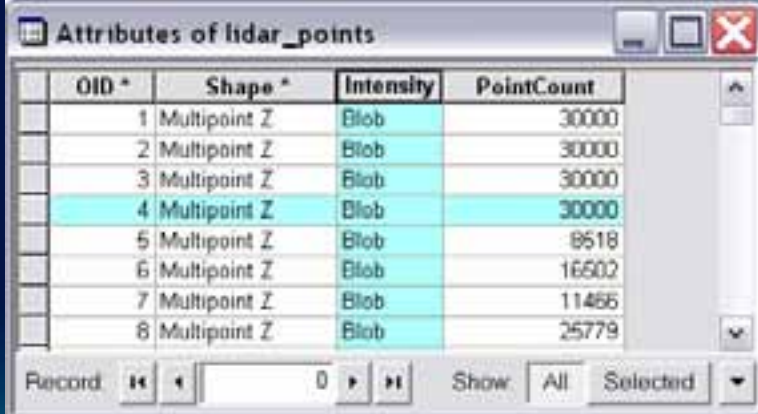
- **LAS files are industry standard binary format for lidar**
- **Loaded using LAS to Multipoint tool**
- **Benefits**
  - **Avoids pitfall associated with ASCII format points**
  - **Extent, point count, and spatial reference in header**
- **Drawbacks**
  - **Built in metadata is lacking in some areas**
    - **Can't always tell how 'raw' the data is**
    - **Classification codes are not described**

# Input Data Formats - ASCII

- **XYZ, XYZI**
  - 3D points
  - Loaded using ASCII3DToFeatureClass GP tool
- **GENERATE**
  - 3D points, lines, polygons
  - Loaded using ASCII3DToFeatureClass GP tool

# Handling Lidar (LAS) Attributes

- Per point attributes (e.g. return number, class code) optionally stored in BLOBs
- A separate BLOB field is used for each attribute
- Array of values with one-to-one correspondence with a set of grouped points is stored with points in same database row

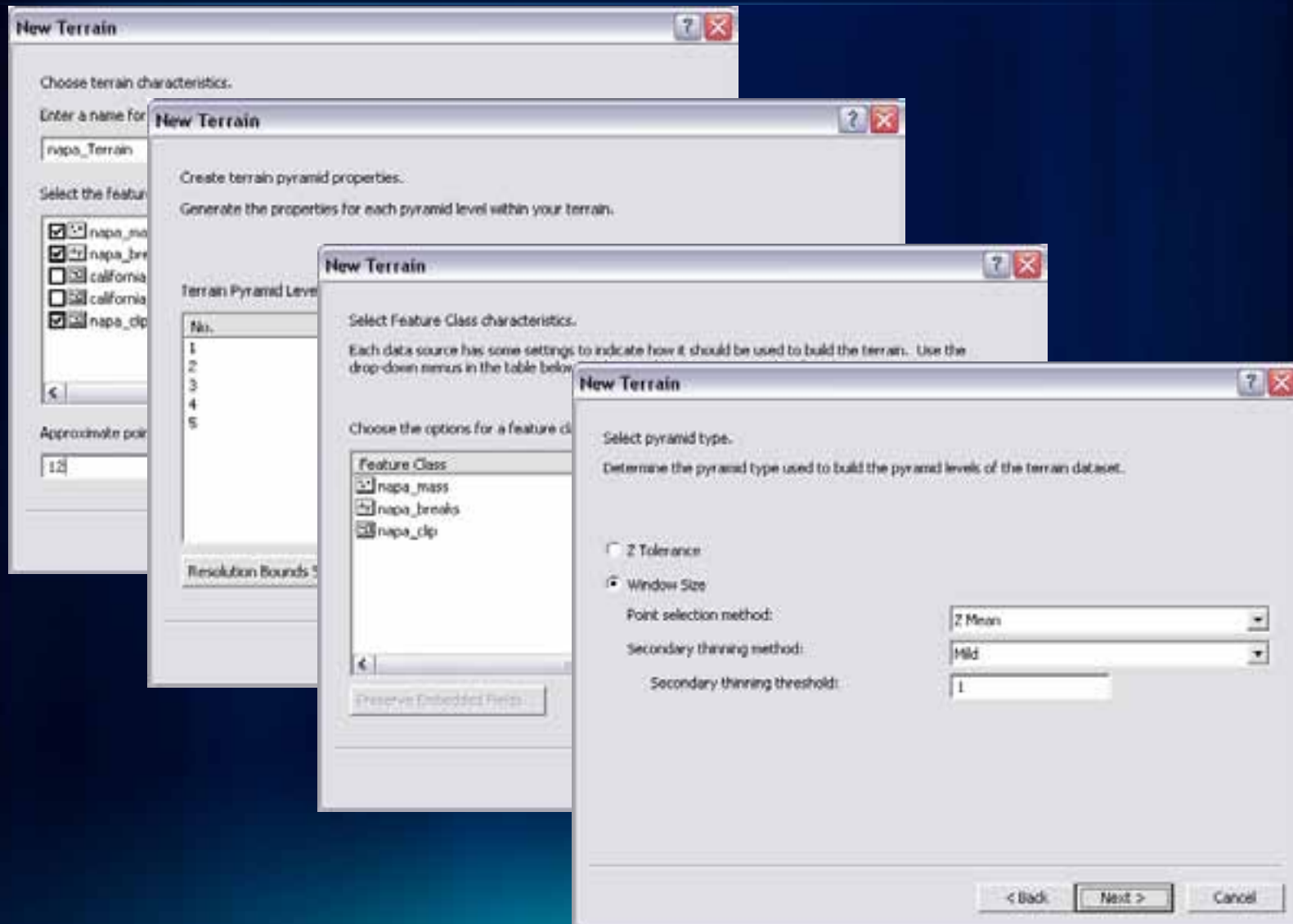


OID *	Shape *	Intensity	PointCount
1	Multipoint Z	Blob	30000
2	Multipoint Z	Blob	30000
3	Multipoint Z	Blob	30000
4	Multipoint Z	Blob	30000
5	Multipoint Z	Blob	8518
6	Multipoint Z	Blob	16502
7	Multipoint Z	Blob	11466
8	Multipoint Z	Blob	25779

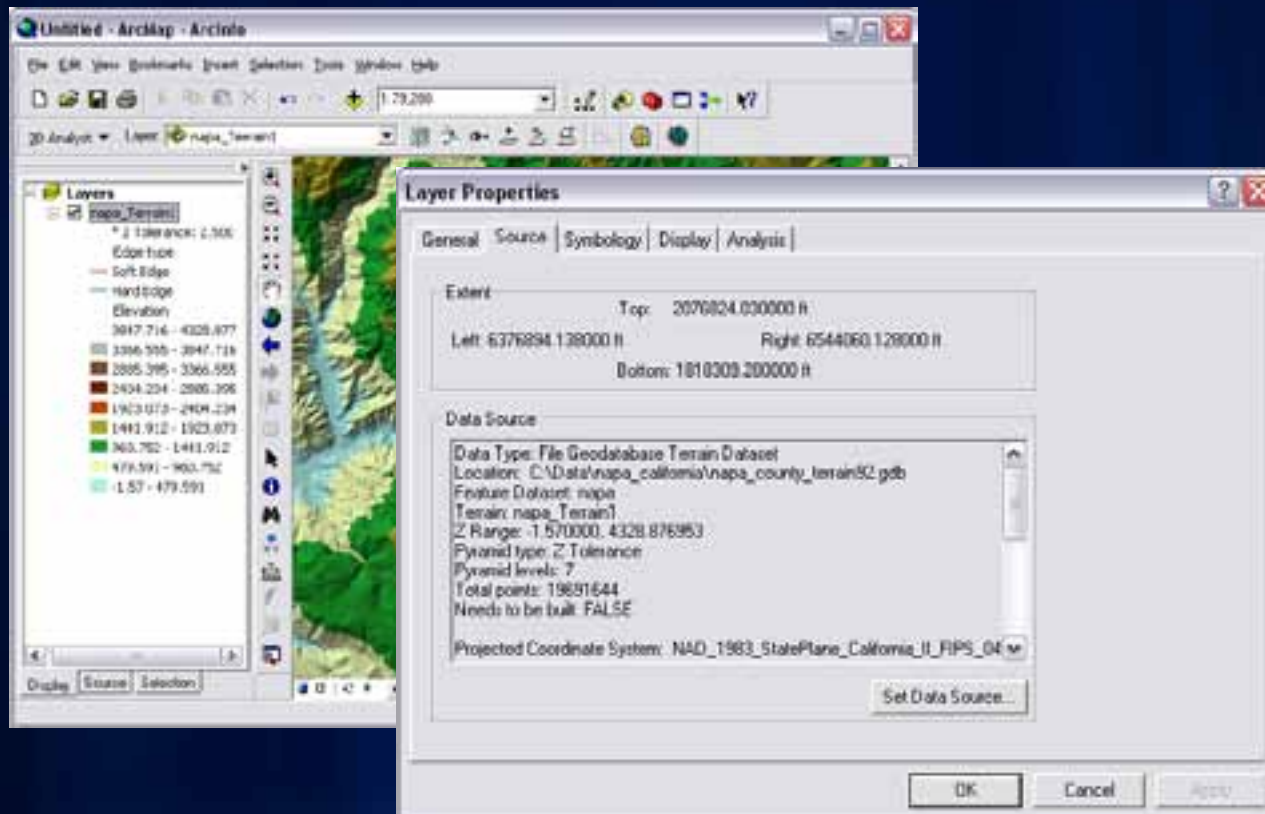
# Editing

- Updates accomplished through edits to source measurements
  - Coarse grained area operators to append, remove, replace mass points
  - Standard/custom edit tools (e.g. ArcEditor) used to modify polylines, polygons, spot heights
  - Terrain rebuild based on dirty-areas
- Support for versioning in SDE

# Terrain Wizard



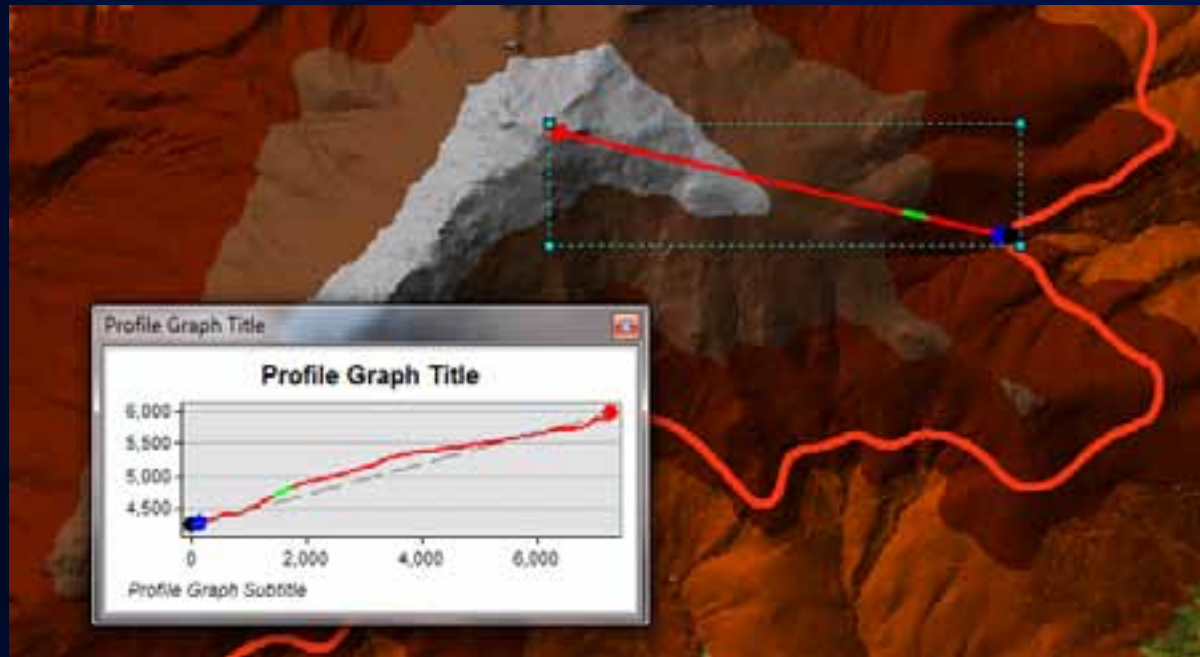
# Terrain Dataset Layer



# Interactive Surface Analysis

- **Interactive surface tools**

*3D Analyst toolbar in ArcMap*





# Geoprocessing Analysis

- **Geoprocessing with Terrain Datasets**

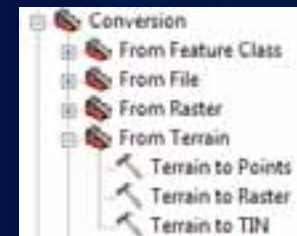
- **Terrain Management toolset** →

- Creation
- Modification



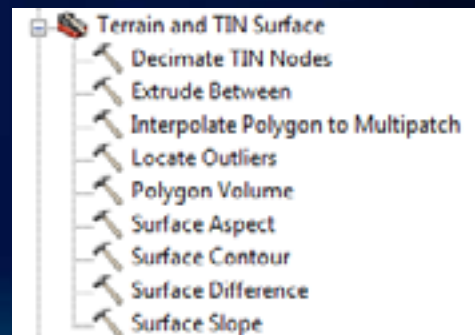
- **Data conversion toolset** →

- Data loading
- Surface conversions



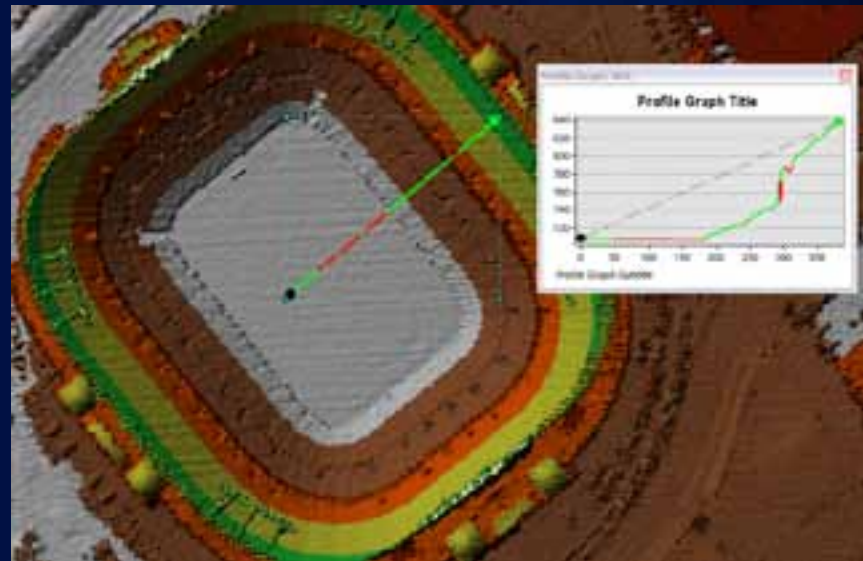
- **Terrain and TIN Surface toolset** →

- Analysis conducted directly on terrains



# Analysis Capabilities for Terrain Datasets

- QA/QC lidar data
- DEM / DSM creation
- Slope
- Aspect
- Contours
- Surface differencing
- Intensity image generation
- Estimating Forest Canopy
- Data area delineation
- Thinning / reducing noise
- Spot interpolation
- Profiling

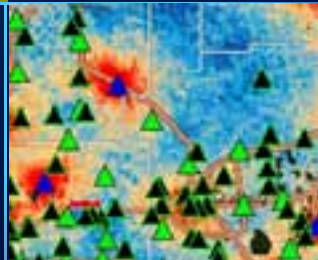
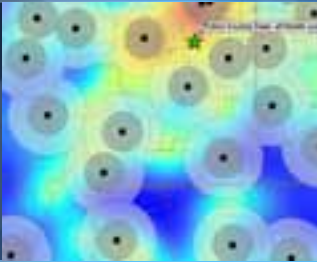


Fulton County Dept. of Health and Wellness/District 3, Unit 2, G1

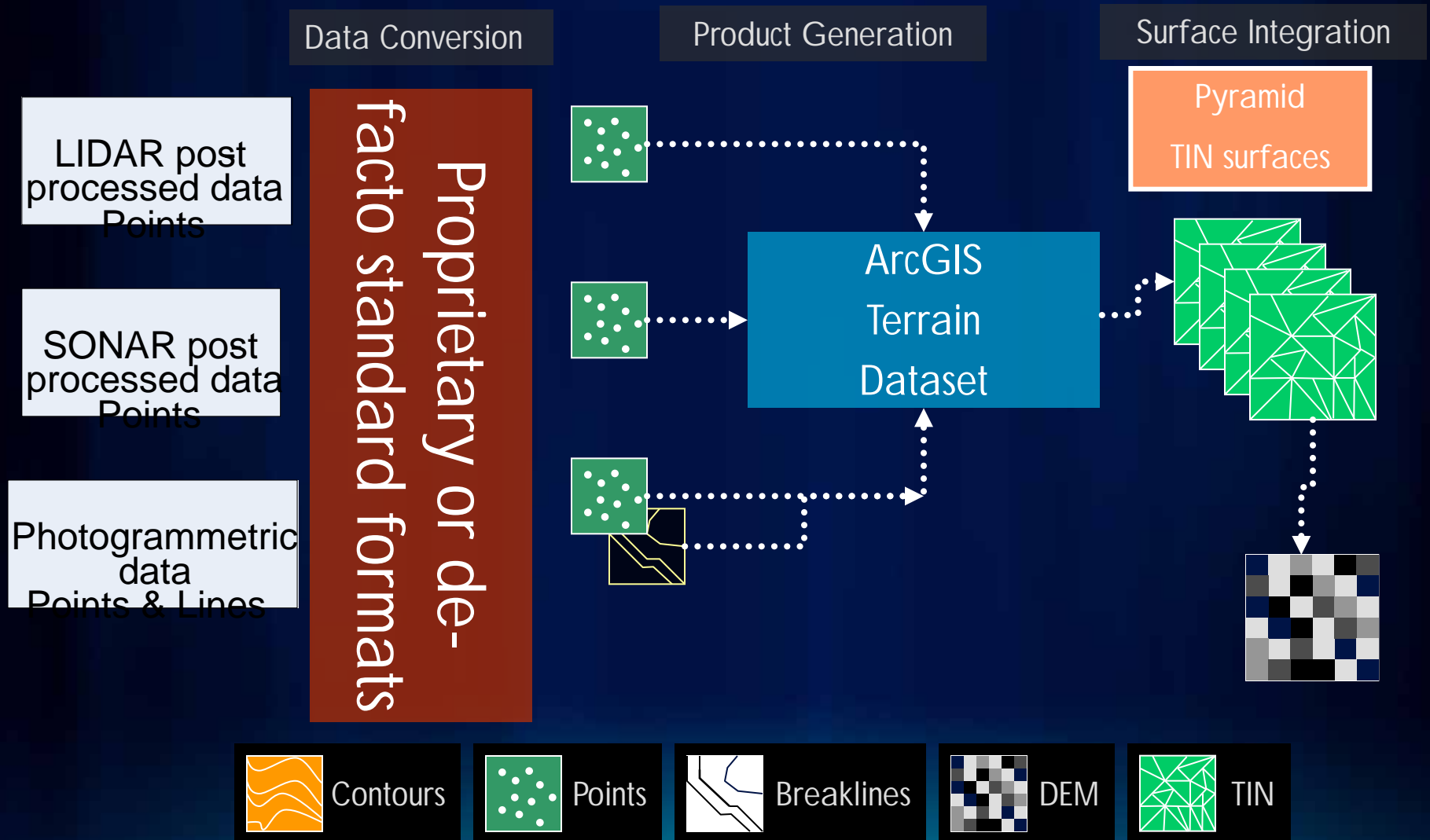
DeKalb County Board of Health

# Working with Terrain Datasets

Lindsay Weitz



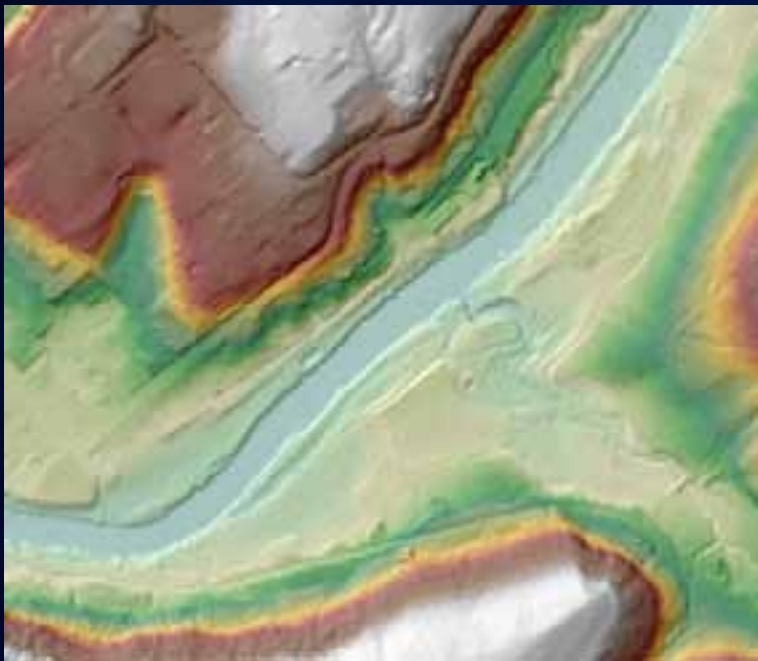
# Terrain Dataset Workflow





# Common Analysis: Creating Raster DEMs and DSMs

Digital Elevation Model



Bare earth surface made using only ground hits.

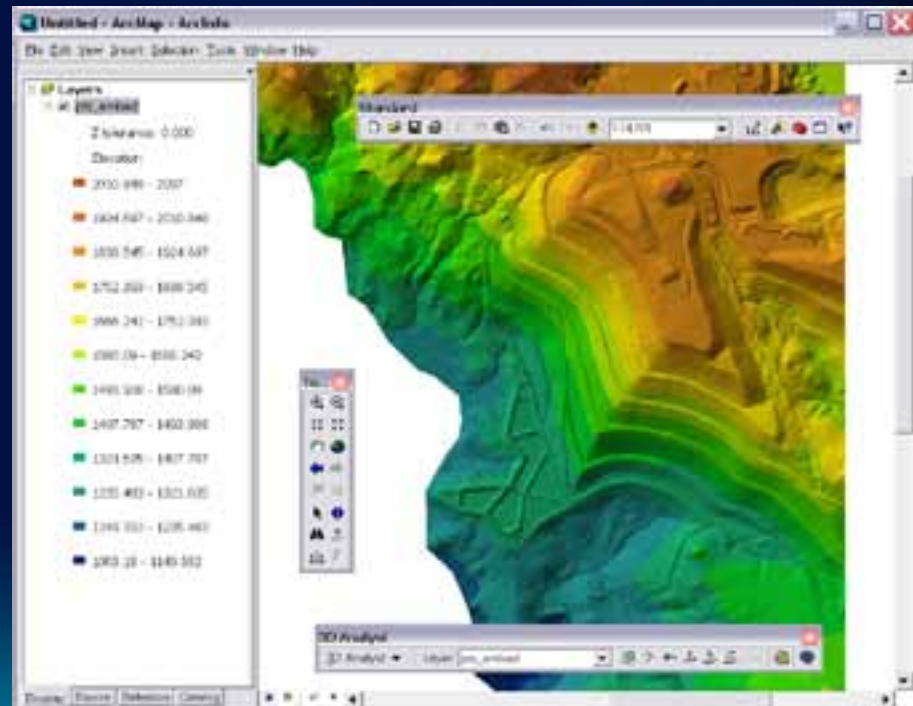
Digital Surface Model



Includes ground, trees, and buildings made using first returns.

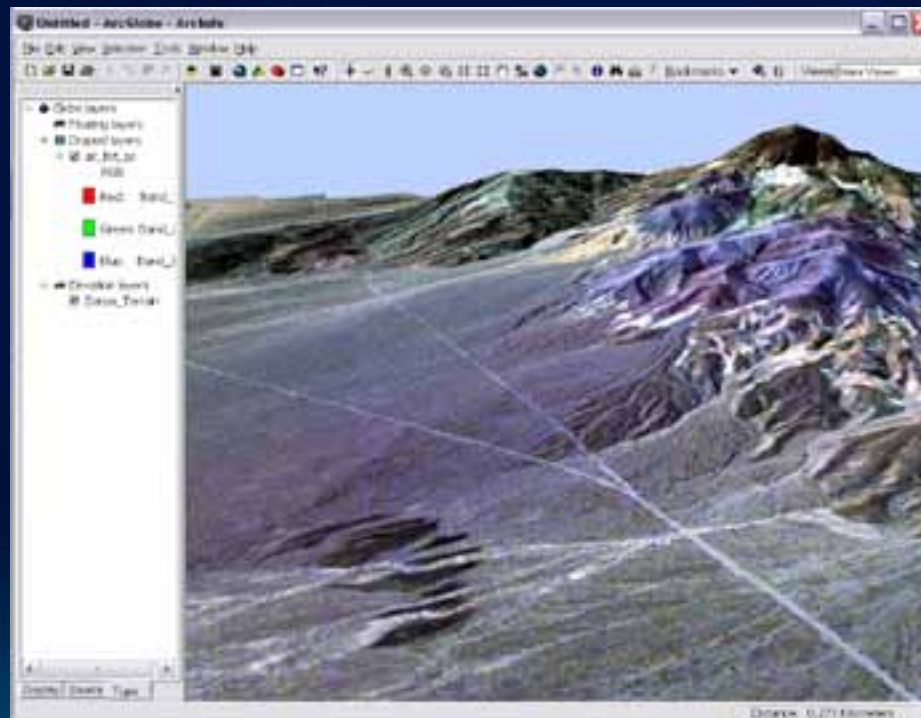
## Mapping and Visualization - ArcMap

- **Displayed as a TIN**
- **Symbology same as TIN**
- **Resolution changes depending on zoom level**



# Mapping and Visualization – ArcGlobe / ArcScene

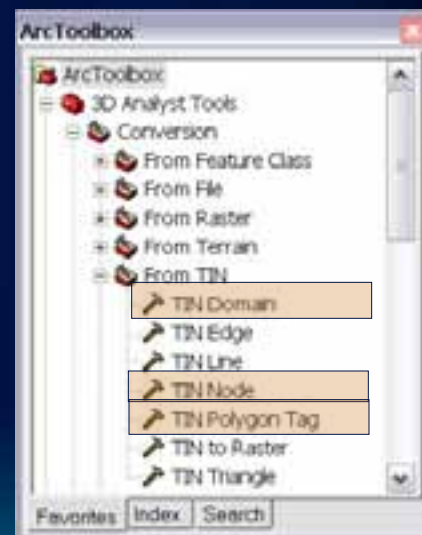
- Terrain datasets can be displayed as either elevation or draped layers in ArcGlobe
- Terrain datasets are not directly supported in ArcScene





# Converting TINs to Terrain datasets

- First, look to see if the source feature data used to make a TIN is available and use it to make a terrain.
- Only if the source feature data is not available:
  - Decompose a TIN to features with GP tools
  - Make the terrain from the features



# Resource – Help System



The screenshot shows the ArcGIS 10 Help application window. The left-hand navigation pane is highlighted with a red box. A blue arrow points from the 'What is a terrain dataset?' link in the pane to the article content on the right.

**What is a terrain dataset?**

A terrain dataset is a multiresolution, TIN-based surface built from measurements stored as Features in a geodatabase. They're typically made from lidar, sonar, and photogrammetric sources. Terrains reside in the geodatabase, inside feature datasets with the features used to construct them.

**Geodatabase.gdb**

- Feature\_dataset**
  - breakline
  - Like\_boundaries
  - Like\_Points
  - Study\_Area

Terrains have participating feature classes and rules, similar to topologies. Common feature classes that act as data sources for terrains include the following:

- Multipoint feature classes of 3D mass points created from a data source such as lidar or sonar
- 3D point and line feature classes created on photogrammetric workstations using stereo imagery
- Study area boundaries used to define the bounds of the terrain dataset

The terrain dataset's rules control how features are used to define a surface. For example, a feature class containing edge of pavement lines for roads could participate with the rule that its features be used as hard breaklines. This will have the desired effect of creating leveler discontinuities in the surface.

Rules also indicate how a feature class participates through a range of scales. Below of pavement features

## Resource – Tutorial

**Exercise 8: Creating and using a terrain dataset**

A terrain dataset is a multiresolution TIN-based surface derived from measurements stored in one or more feature classes in a geodatabase.

In this exercise, you will use preprocessing tools to load surface data into a geodatabase, construct a terrain dataset, and use the terrain inside ArcMap and ArcToolbox.

**Loading surface feature data into a geodatabase**

In this scenario, you have lidar points and photogrammetric breaklines stored in two separate ASCII text files. This data will be used to construct your terrain dataset. To accomplish this, you need to import them into feature classes that reside in a feature dataset. The terrain will be generated in the same location as the source data. You've been provided with a file geodatabase with a feature dataset. It contains two polygon feature classes: one is for lakes, the other to delineate the study area. The initial step will be to import the two ASCII files into the feature dataset as feature classes; one feature class will delineate the photogrammetric breaklines, while the other feature class will contain the lidar points.

**Steps:**

1. Start ArcCatalog by clicking **Start > All Programs > ArcGIS > ArcCatalog 10.1**.
2. Click **Customize > Extensions**. The **Extensions** dialog box opens.
3. Verify the **3D Analyst** option is enabled. If it's not, check it and close the dialog box.

**Contents:**

- Introduction
- Data Requirements
- Data Model
- Data
- Data Sources

## **Known Limits – Personal Geodatabase**

- **Not storage efficient**
- **Limited 2GB capacity**
- **Significant performance drop before capacity reached**
- **Not recommended for terrains over 20 million points**

## **Known Limits – No Geographic Coordinates**

- **Terrain dataset use Delaunay triangulation**
  - Method is valid only when data is projected
- **Tools on user interface will prevent creation of terrains in feature datasets that use Angular Coordinate Systems**

# Best Practices

- LAS Over ASCII
- Use File or SDE GDB (Personal - 2GB Limit)
- Consider file or enterprise geodatabase for large datasets (> 1-2 billion points)
- Terrain dataset must be stored in a feature dataset
- Use projected coordinates
- Use Consistent Units (x, y, and z) and contiguous datasets
- Breakline enforcement
- Use ArcGIS for lidar derived rasters

## Workflow to serve elevation:



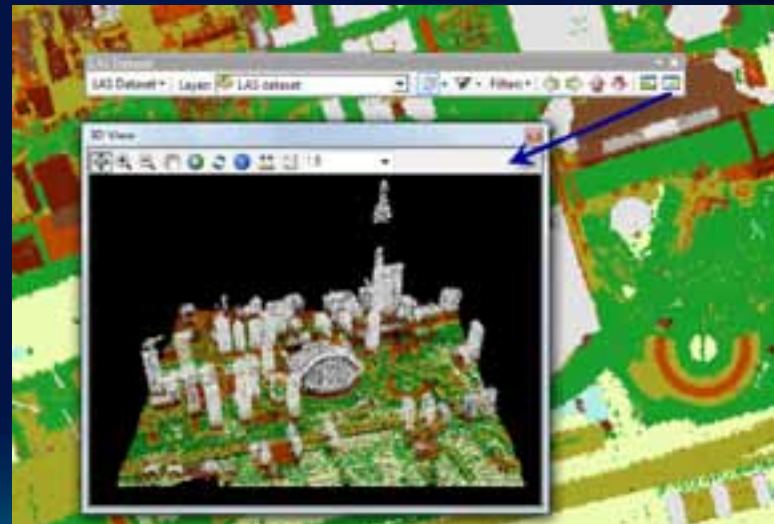
# Performance and Size Estimates

- **Import:**
  - 800 million LAS points per hour
- **Terrain pyramid build:**
  - 80 million points per hour using z-tolerance filter
  - 400 million points per hour using window size filter
- **Storage:**
  - 150 million points (geometry only) = 1GB
  - Terrain pyramid will be roughly same size as source multipoint feature class so total storage can double
    - Can use option to *embed* points to recover space

Timed using HP xw4400 Core2 Duo 2.67 GHz PC  
Reads/writes using same drive  
File Geodatabase

# What's Coming at ArcGIS 10.1

- New ArcGIS LAS dataset to support lidar directly
- Quickly view lidar data in 2D and in 3D
- Perform quality assurance checks on LAS files
- Update lidar class codes





# Questions?

Please fill out the evaluation form.....

[www.esri.com/sessionevals](http://www.esri.com/sessionevals)